SECTION E - CONDUIT

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SECTION E - CONDUIT

I. INTRODUCTION

One of the more critical elements in the safety of a dam is the conduit that carries water through the embankment. Not only must the conduit be watertight against internal water pressures, it must be designed to carry exterior vertical and transverse loads to resist structural failure. It must be set on a grade that takes into account the magnitude of foundation settlement and the variation of this settlement along its length. It must allow for readjustment of the individual pipe lengths without failure of the joints. These joints must allow for "stretch" in the conduit as a result of foundation displacement. And lastly, the backfill must be carefully placed along the conduit so that seepage water will not find a more favorable path along the contact surface than that it must face through the embankment itself.

These conditions are met in part by the selection of the proper conduit type and strength, whether it be a rigid pipe in a concrete cradle, a flexible pipe, or a monolithic box, set on a grade considering camber requirements. Adding anti-seep collars insures the path along the contact zone will be a longer seepage line than that through the embankment. Of course all of these precautions mean little if the installation does not conform to the requirements of the construction specifications.

II. GENERAL CRITERIA

Because the conduit is such a vital part in the safety of the dam, criteria is very explicit and limiting in those cases where loss of life could result from embankment failure. To ensure that these limiting criteria are not overlooked, the following tabulation of existing engineering memoranda is included and these must be complied with as each restriction applies:

1. Engineering Memorandum SCS-27 (Rev.) Earth Dams.

2. Engineering Memorandum SCS-42 (Rev.) R/C Pipe Drop Inlet Barrels.

3. Engineering Memorandum SCS-58, Corrugated Aluminum Pipe and Fittings.

In addition to the memoranda, procedures for analysis are continued in the following:

1. NEH, Section 6, Structural Design

2. Technical Release No. 5, The Structural Design of Underground Conduits

Appropriate specifications include:

Spec. No. 41, R/C Pressure Pipe
Spec. No. 51, Corrugated Metal Pipe Conduits
Spec. No. 52, Steel Pipe Conduits
Spec. No. 541, R/C Pressure Pipe
Spec. No. 542, Concrete Culvert Pipe
Spec. No. 551, Zinc-Coated Iron or Steel Corrugated Pipe
Spec. No. 552, Aluminum Corrugated Pipe
Spec. No. 553, Steel Pipe and Fittings

III. CONDUIT TYPES

A. Precast Concrete Pipe

Four types of precast pipe are recommended as suitable for use as a conduit through an embankment.

1. ASTM 361, R/C Low Head Pressure Pipe
2. AWWA 300, R/C Steel Cylinder Type Non-Prestressed
3. AWWA 301, R/C Steel Cylinder Type Prestressed
4. AWWA 302, R/C Non-Cylinder Type Non-Prestressed

The procedures presented in Technical Release No. 5 should be used in determining structural requirements of the pipe.

General details of precast pipe are shown on Figure E-1. The inside diameter listed on this figure for the different types in all inclusive. Incremental sizes and some types are not available from all plants. Freight costs can add considerably to construction costs for a particular job and should be a consideration in comparing alternate details.

In addition to the precast pipe listed above, a concrete cylinder pipe complying with Federal Specification SS-P-381 has been used in composite construction as a liner in a job-placed reinforced concrete conduit.

Conduit wall thicknesses have been listed in Table E-1 for ready reference as required.

B. Flexible Conduits

Of the flexible conduits, a corrugated metal is the most commonly used. Corrugations may be annular or spiral and the conduit made of galvanized iron or aluminum.

Use of corrugated pipe is limited to fill heights of 25'-0" or less.

Aluminum pipe shall not exceed 36" diameter and internal pressures shall be limited to 15 feet of head. Aluminum material shall not be used where the pH is less than 4 or greater than 9.

Where the product of the storage in acre feet times the height of the dam[1/] is less than 3000 and meets the conditions above, the following tables apply:

Recommended corrugated metal pipe gages for various pipe diameters and fill heights are given in

1. Table E-3 for corrugated steel.

2. Table E-4 for corrugated aluminum.

Special precautions should be taken in the backfill operation. Because of its light weight, the pipe will be displaced upward when backfilling in the lower third. To avoid this displacement there is a tendency by the construction crew to under-compact this material. This results in a poor contact zone between the soil and conduit with a potential for piping and eventual embankment failure. To insure adequate compaction, the conduit should be preloaded with sandbags to resist the uplift until the lower 120° of the conduit is backfilled. As an alternate the pipe can be bedded in concrete.

Welded steel pipe may be used as a liner for a monolithic conduit of small diameter. As such it no longer is classed as a flexible pipe.

C. Monolithic Conduits

Poured in place conduits are used in many installations for both the small diameter as well as the larger box conduit. In the small diameter conduit a welded steel pipe is used as a liner which serves as an interior form. The joints of this pipe are "stab" type with a rubber ring. A trench is excavated to neat lines and serves as the bottom and side exterior forms for the conduit walls.

On a non-compressible foundation no joints are provided in the concrete. For a compressible foundation a joint similar to the detail shown on Figure E-3 or E-5 is used.

1/ Defined as the difference in elevation in feet between the emergency spillway crest and the lowest point in the original profile on the centerline of the dam.

Conduit wall thickness varies with the soil type in the foundation and embankment as well as the height of fill over the conduit. Figure E-2 was developed to size the conduit wall thickness and reinforcement for trial sections. Successive choices between two types of conduit embedment conditions, three types of foundations, and finally three types of embankment soils narrows down the problem to the trial section. An extension of the final zone to an intersection with the height of earth cover will indicate the governing structural condition. From this point a vertical projection to the W line upward in the shear zone, downward in the moment zone, and then a horizontal projection to conduit diameter will provide thickness and transverse reinforcement requirements. Longitudinal reinforcement is arbitrary but should consist of at least eight #5 bars for conduit diameters over 12 inches. Lateral spacing of longitudinal bars should not exceed 12 inches.

IV. JOINTS

The integrity of the entire installation depends to a great extent on joint detail. For concrete conduits any rotation due to settlement and elongation of the conduit must take place at the joints. Procedure for calculating joint extensibility is given in Technical Release No. 18.

Recommended joint detail for rigid circular conduits consists of an "O" ring rubber gasket seated in a groove in a steel spigot ring to be inserted in a steel bell. A sectional detail of this joint assembly is shown on Figure E-1. The rest of the joint details shown on this figure are not acceptable in conduits through embankments.

Spigot ring cross section will vary with manufacturer conduit diameter and joint extension requirement. In western areas Carnegie shape M 3818 and M 3516 are commonly used. The annular space between the adjacent pipe ends should be filled with a mastic joint sealer for joint flexibility instead of the cement grout normally recommended by the manufacturer.

The bell and spigot joint is used for both the precast pipe as well as the composite construction (shown in Figure E-6).

For monolithic concrete conduits with a rectangular opening the joint detail will vary with conduit size. Several details are shown on Figures E-3 and E-5.

The Carnegie shape joint mentioned above is recommended for welded steel pipe. An alternate joint would be a Dresser coupling. Least desirable is a welded joint.

For corrugated metal conduits the watertight coupling band is used.

V. ANTI-SEEP COLLARS

To insure that any seepage along the contact surface between the conduit and embankment will be less than that through the soil itself, anti-seep collars are used. These are projections from the conduit that effectively increase the length of the seepage path.

Anti-seep collars must be structurally independent of the conduit. To insure this, roofing felt and preformed joint filler is used in the contact surfaces between the conduit and collar.

If the collars are placed too close together, the seepage path would tend to bridge the space between the collars since this is the path of least resistance. Although keeping the seepage from the conduit-soil contact surface, close spacing would require an excessive number of collars. Anti-seep collar spacing should be restricted to a minimum of 10'-0 and a maximum of 25'-0.

The length of the projection and the number of anti-seep collars varies with agency requirements. Normally a 2'-0 vertical projection is recommended and a number of collars equivalent to a 15% increase in conduit length. Various soil types and zoned embankments add to the design problem. To simplify the proportioning of anti-seep collars, Figure E-8 was developed. On it, embankment types and soil types are considered in selecting either a 15% (1.15) or a 20% (1.20) increase in seepage length. In zoned fills the vertical projection should be increased so that close spacing can be avoided and still retain the collars in the impervious zone where they will do the most good.

VI. CAMBER IN CONDUITS

Foundation settlement can be expected under the combined weight of an embankment and the water impounded in the reservoir. The magnitude of settlement is a function of the applied load; depth, relative density, moisture content and permeability of compressible foundation materials; and time. Generally clays, silty clays and medium and high plastic silts are the most compressible materials. Settlement characteristics of these materials must be determined by consolidation tests on undisturbed samples. The magnitude of settlement is computed using procedures of Standard Drawing 7-N-15474 (not included here) and is part of embankment design.

Camber is designed for a conduit so that as settlement occurs, the invert of a cambered conduit theoretically approaches uniform slope. Camber for a conduit can be defined as a curve which approximates the inverse of the settlement curve. If a conduit is not cambered a sag will develop as settlement occurs, the conduit joints will spread at the bottom, the conduit can leak and cause serious damage to the structure.

Camber is designed for a conduit in addition to computing the joint extensibility requirements in accordance with Technical Release 18. Settlement does not occur as a gradual advancement of a smooth curve. Although the final settlement curve is approximately a uniform curve, enough irregularity will exist in the conduit profile to require adequate joint extensibility.

The simplest method of computing camber is to use two lengths of uniform slope as shown in Figure E-10. This method is used only for short conduits with small settlement. The joint at the grade change is the only one designed not to spread as settlement occurs.

A preferred method is to design a curve approximating the inverse of the settlement curve. Theoretically, all joints on such a curve are designed not to spread as settlement occurs. A procedure for this method is given below.

Because of the many variables affecting the magnitude of settlement, it is unwise to innocently assume that all foundations can be treated alike. However, for small dams less than 30 feet high on shallow foundations, the magnitude of settlement is small, precise computations for camber are seldom justified and the following general assumptions can be made.

1. Shallow foundation is defined as depth to noncompressible material less than one-half the height of dam.

2. Depth of compressible foundation is uniform under the dam.

3. Settlement curve is a parabolic curve with maximum settlement near the centerline of the dam.

4. Maximum settlement can be estimated to be 4 percent to 5 percent of foundation depth when not otherwise computed.

In the following procedure certain items are fixed by site conditions and the embankment design. These include:

1. L - Total length of conduit.

2. Y - Total drop between inlet and outlet of conduit.

3. Δ - Magnitude of settlement, assumed to be largest at embankment centerline.

4. δ - Camber height at point X.

5. ℓ - Length of standard pipe or conduit sections to be used. ($\not\ell$ is a partial length.)

A joint should be placed as near as possible to the centerline of the dam. Negative slope in the cambered conduit should be avoided. Use zero slope through those reaches where camber design indicates negative slope is necessary.

Figure E-11 is a dimensionless plot of settlement vs. conduit length for a parabolic settlement curve.

Table E-2 contains data for computing maximum deflection angle at a joint for various lengths of standard reinforced concrete pipe.

Procedure for Tabular Computations

1. Determine number of pipe lengths required (n = lowest whole number).

$$n = \frac{L}{\ell}$$

2. Determine $\ell = L - n\ell$

3. Determine $L_1 \simeq \frac{1}{2} W + Z(\text{El. top of Dam} - \text{El. Inlet})$.

   This should be a multiple of ℓ so that a pipe joint falls near centerline of dam.

4. Determine $L_2 = L - L_1$

5. Determine average uniform slope and tabulate elevation of average grade line at each pipe joint (Col. 7).

6. Compute camber: Refer to page E-9 and 10 for tabulation form.

   a. Tabulate ℓ_1 and ℓ_2 (Col. 2).

   b. Tabulate $\Sigma\ell_1$ and $\Sigma\ell_2$ (Col. 3)

   c. Tabulate $\frac{\Sigma\ell_1}{L_1}$ and $\frac{\Sigma\ell_1}{L_2}$ (Col. 4)

   d. From Figure E-11 read $\frac{\delta}{\Delta}$ (Col. 5)

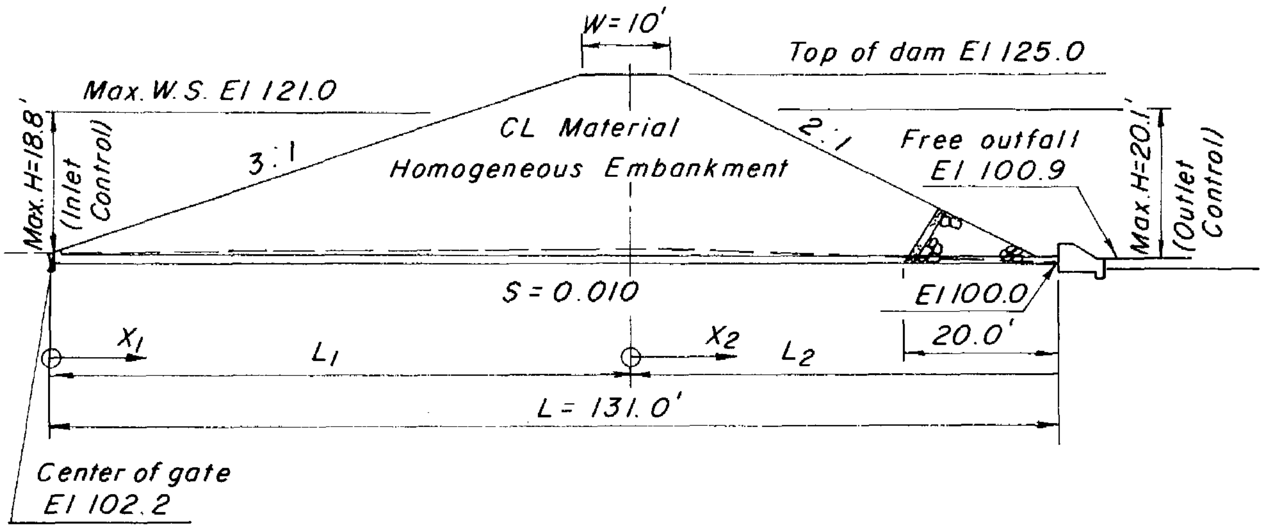
   e. Compute camber = $\delta = \frac{\delta}{\Delta}\Delta$ (Col. 6)

   f. Tabulate average grade elevation - elevation of invert at upstream end less drop per length of pipe (Col. 7).

   g. Compute camber grade elevation = average grade elevation plus camber (Col. 6 + Col. 7) = (Col. 8).

VII. EXAMPLE

Given: The earth dam data used in the example problem of Section B, and choices of 20 in. steel pipe, 21 in. R/C pipe, or 24 in. CMP.



$L_1 + L_2 = 131$

$\Delta = 0.4$ ft (determined by soils engineer)

$\ell = 16$ ft (use standard pipe)

$Y = 1.31$ ft

Determine:

1. Camber for the outlet conduit by computing joint elevations.

2. The number and spacing of collars, comparison of conduit types and quantities for 20 in. steel pipe, 21 in. R/C pipe and 24 in. CMP.

Problem Analysis:

1. Find camber:

   a. Determine conduit length.
   b. Determine the number of full pipe lengths.
   c. Determine L_1 and L_2.
   d. Determine the average uniform slope.
   e. Determine drop per pipe length.
   f. Tabulate ℓ_1 and ℓ_2.

g. Tabulate $\Sigma\ell_1$ and $\Sigma\ell_2$ (note 2 horizontal scales on Figure E-6)

h. Tabulate $\dfrac{\Sigma\ell_1}{L_1}$ $\dfrac{\Sigma\ell_2}{L_2}$

i. Determine $\dfrac{\delta}{\Delta}$ from Figure E-11.

j. Determine δ

k. Determine average grade elevation.

l. Determine camber grade elevation.

2. Details:

a. Determine the number of collars, Figure E-8.
b. Determine encasement and collars for 20 in. steel pipe.
c. Find combination of 21 in. R/C pipe, cradle and collar meeting strength requirement.
d. Check minimum gage and diaphragm size for 24 in. CMP.

Solution:

1. $L_1 = \frac{1}{2}W + 3(1250 - 101.31) = 5 + 71.1 = 76.1$

Use L_1 = 80 ft = 5 pipe lengths

Number of full pipe lengths $= \dfrac{131}{16} = 8$

$L_2 = 131 - 80 = 51' = 3 - 16'$ lengths $= 1 - 3'$ length

Drop per length of pipe: $D_1 = 16(0.010) = 0.16$

$D_2 = 3(0.01) = 0.03$

1	2	3	4	5	6	7	8
Joint No.	ℓ_1	X_1 or $\Sigma\ell_1$	$\frac{\Sigma\ell_1}{L_1}$	$\frac{\delta}{\Delta}$	δ	Average Grade Elevation	Camber Grade Elevation
1	0	0	0	0	0	101.31	101.31
2	16	16	0.20	0.37	0.15	101.15	101.30
3	16	32	0.40	0.63	0.25	100.99	101.24
4	16	48	0.60	0.84	0.34	100.83	101.17
5	16	64	0.80	0.96	0.38	100.67	101.05
6	16	80	1.00	1.00	0.40	100.51	100.91

1	2	3	4	5	6	7	8
Joint No.	ℓ_2	X_2 or $\Sigma\ell_2$	$\frac{\Sigma\ell_2}{L_2}$	$\frac{\delta}{\Delta}$	δ	Average Grade Elevation	Camber Grade Elevation
7	16	16	0.31	0.90	0.36	100.35	100.71
8	16	32	0.63	0.61	0.24	100.19	100.43
9	16	48	0.94	0.12	0.05	100.03	100.08
10	3	51	1.00	0	0	100.00	100.00

2. Details

a. Determine the number of cutoffs and spacing:

The dam is a homogeneous embankment type (1) with CL material. Referring to Figure E-8 shows that the 1.15 chart is recommended. Enter the 1.15 chart with L' = 111 ft and read V = 2.5 ft for n = 4, V = 2.0 ft for n = 5, and V = 1.5 ft for n = 6. Since V = 2.0 ft is recommended as a national standard, use n = 5. The spacing is then determined by $S = \frac{L'}{n + 1}$ or $S = \frac{111}{6} =$ 18.5 ft, use S = 18.5 ft.

b. Check 20" R/C monolithic conduit.

Using a projecting conduit condition with a foundation of high liquid limit clay, an embankment material will be assumed to be of low plasticity.

With a height of earth cover of 25 ft and a pipe diameter of 20 in., enter Figure E-2 as shown by example. Find t = 6 in. (minimum thickness) and steel = #5 @ 12 in.

Quantities from Table J-E1 show this conduit to require (131)(0.19) = 24.9 cu yd of concrete and (131)(11.04) = 1446 lb of steel.

Using D + 2t = 2'-8" and V = 2.0 ft from Table J-E2, find the anti-seep collars require (5)(0.847) = 4.2 cu yd of concrete and (5)(47.2) = 236 lb of steel.

c. Check 21" R/C conduit.

Table J-E4 lists 21" R/C pipe as being available meeting the AWWA C-302 (f_c = 6000 psi), ASTM C-361.

Using the procedures as presented in Technical Release 5 find the combination of pipe and cradle that satisfies the strength requirements.

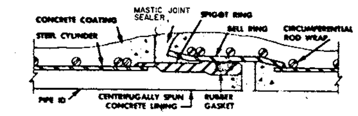
d. Check for 24" CMP.

If corrugated metal pipe is acceptable, minimum pipe gages are listed in Tables E-3 and E-4.

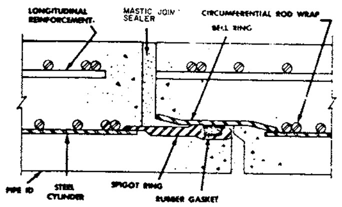
For a fill height of 25 ft, find required pipe gage of 16 for corrugated steel and 12 gage for aluminum.

For either steel or aluminum, the standard manufactured anti-seep collar is 72" x 72" of 14 gage material. Details for both collar and coupling band are shown on Figure E-9.

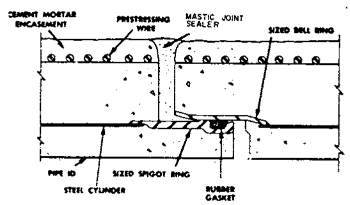
CONCRETE CYLINDER



Federal Specification SS-P-381
Diameters 12 thru 36 inch;
Pressures to 250 psi
Prestressed

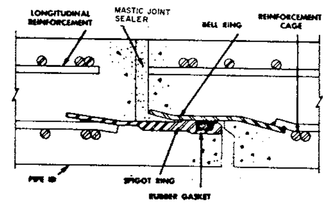


AWWA Standard C300
Not prestressed
Diameters 20 thru 96 inch
Pressures 40 thru 260 psi

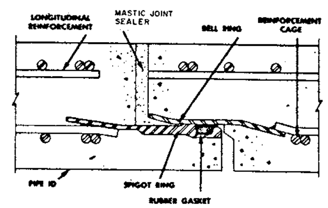


AWWA Standard C301
Prestressed
Diameters 12 thru 96 inch
Pressure as specified

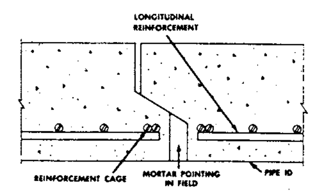
REINFORCED CONCRETE



ASTM Designation C361
Diameters 12 thru 168 inch
Pressures to 125 feet of head

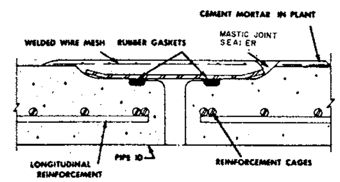


AWWA Standard C302
Diameters 12 thru 96 inch
Pressures less than 45 psi

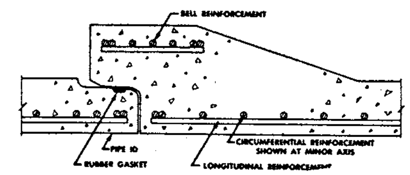


ASTM Designation: C 76
Diameters 12 thru 108 inches

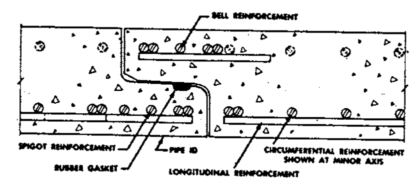
ALTERNATE JOINT DETAIL



AWWA Standard C302

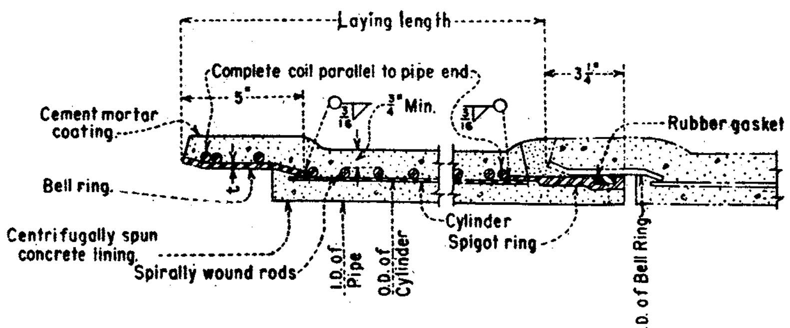


AWWA Standard C302

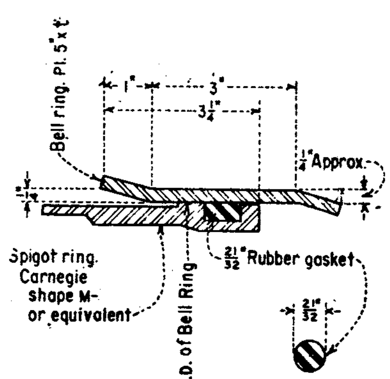


AWWA Standard C302

JOINT DETAIL



SECTIONAL DETAIL



RING ASSEMBLY

Note:

Alternate Joint Details shown are typical of the variation in joint types that are available for most classes of pipe. They are not all acceptable on conduits thru dam embankments.

The ring assembly detail shows a steel ring joint for minimum joint extensibility.

FIGURE E-1
TYPES OF PRECAST CONCRETE PIPE
EWP Unit Portland, Oregon

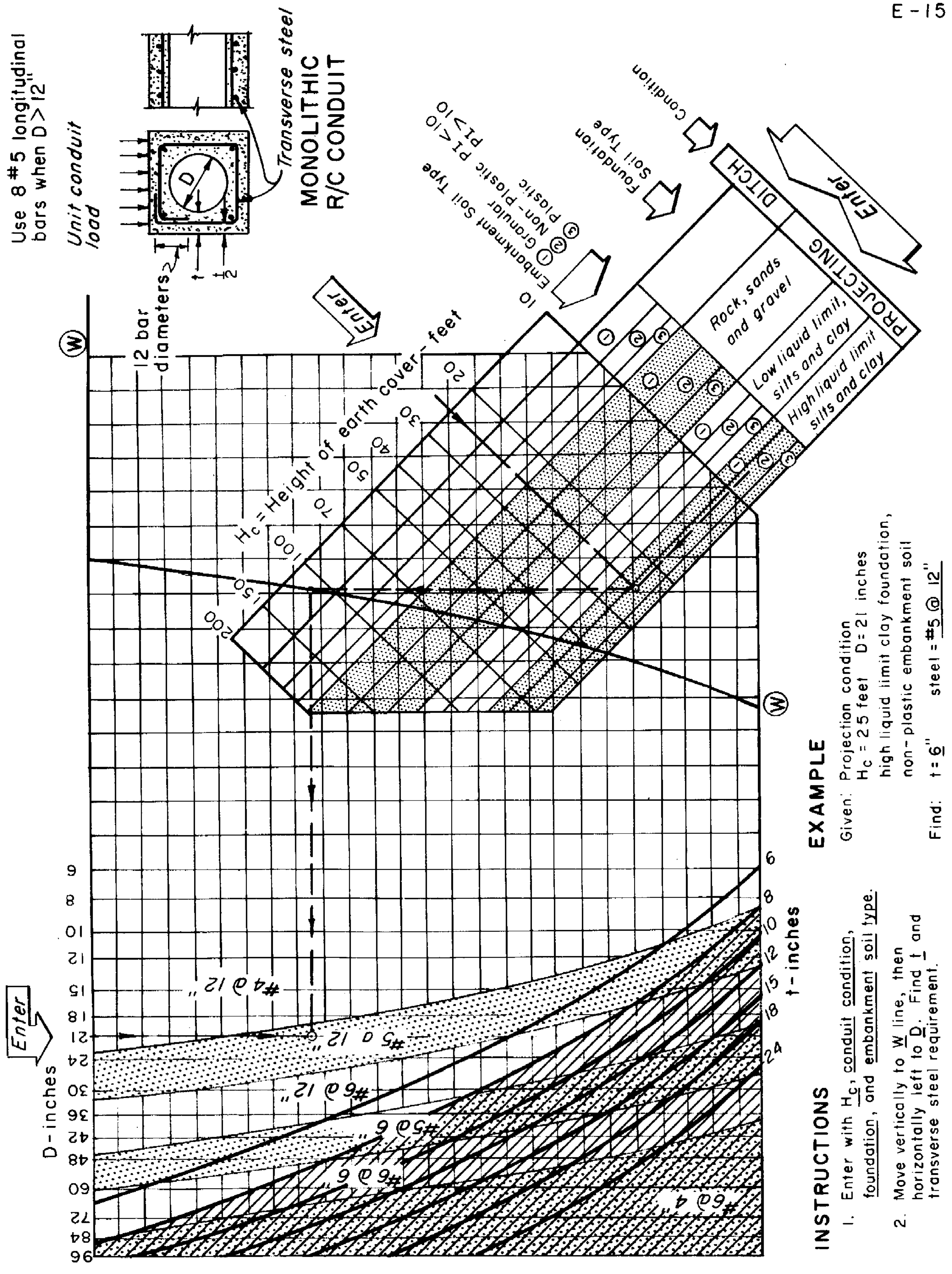
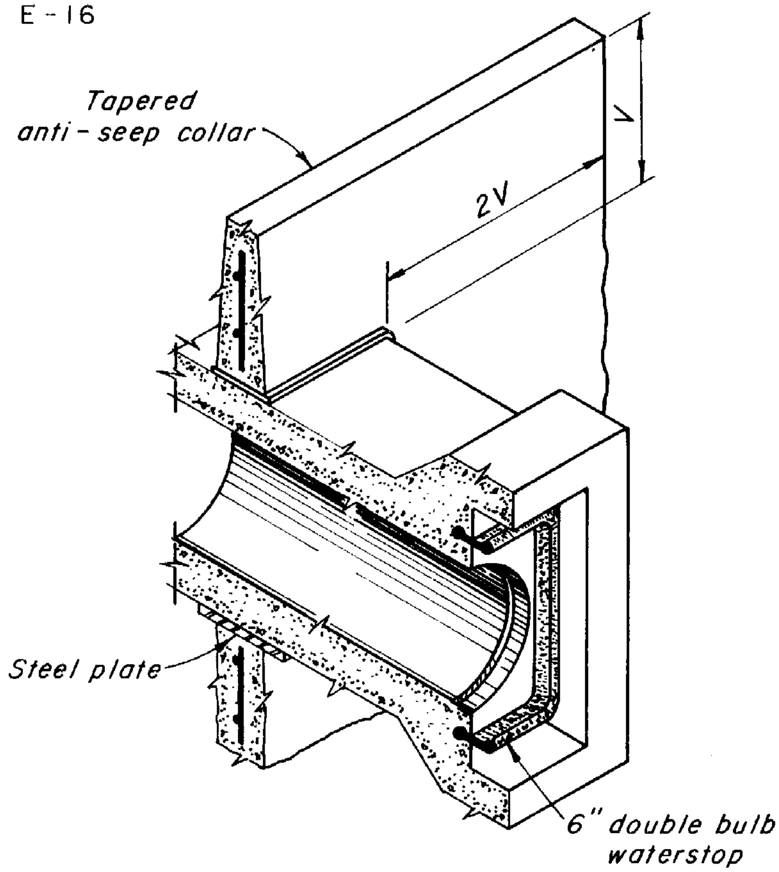
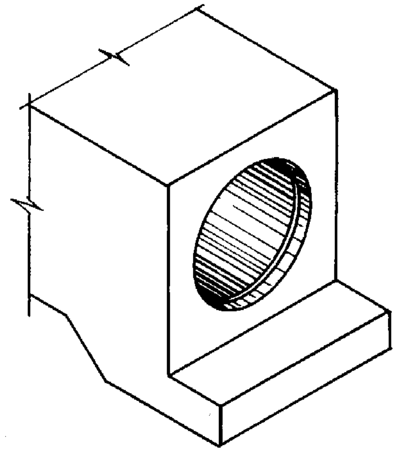


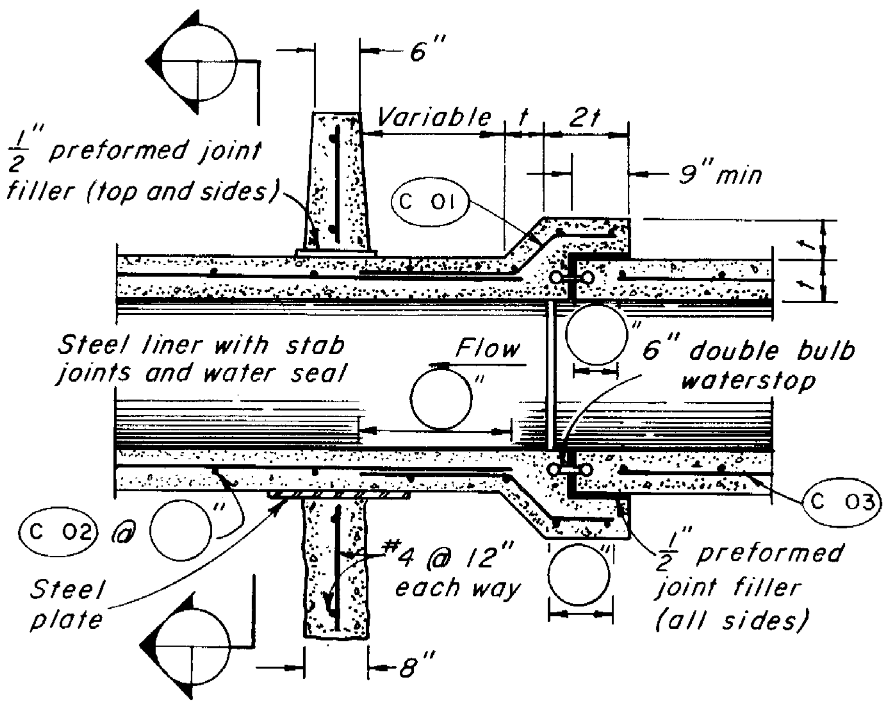
FIGURE E-2
MONOLITHIC R/C CONDUIT WITH STEEL LINER

EWP Unit Portland, Oregon

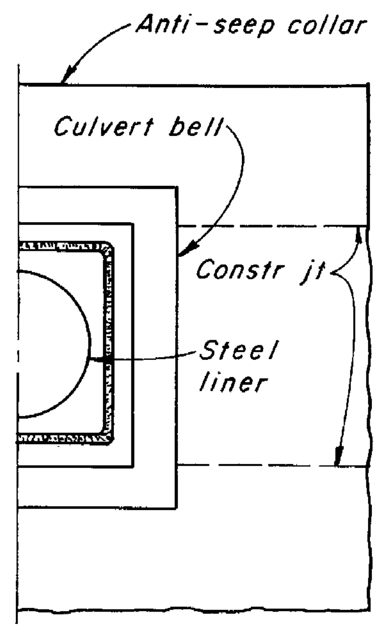




ALTERNATE



SECTIONAL ELEVATION



END VIEW

ANTI - SEEP COLLAR

Note:

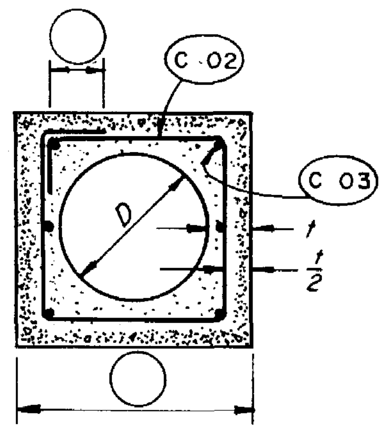
Max. joint spacing = 32.0'

Refer to Figure E-2 for thickness t and reinforcing requirements

FIGURE E-3

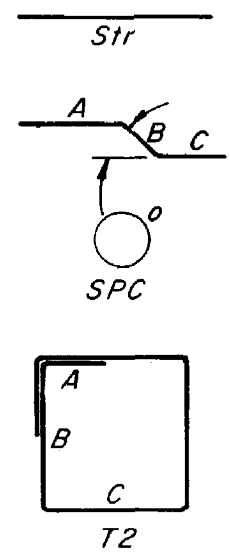
R/C MONOLITHIC CONDUIT DETAIL

EWP Unit Portland, Oregon



SECTION

Note.
Use 8 longitudinal bars when D > 12"



BAR TYPES

Not to Scale

STEEL SCHEDULE									
Location	Mark	Size	Quan.	Length	Type	A	B	C	Total Length
CONDUIT ENCASEMENT									
	C 01				SPC				
	C 02				2				
	C 03				Str				

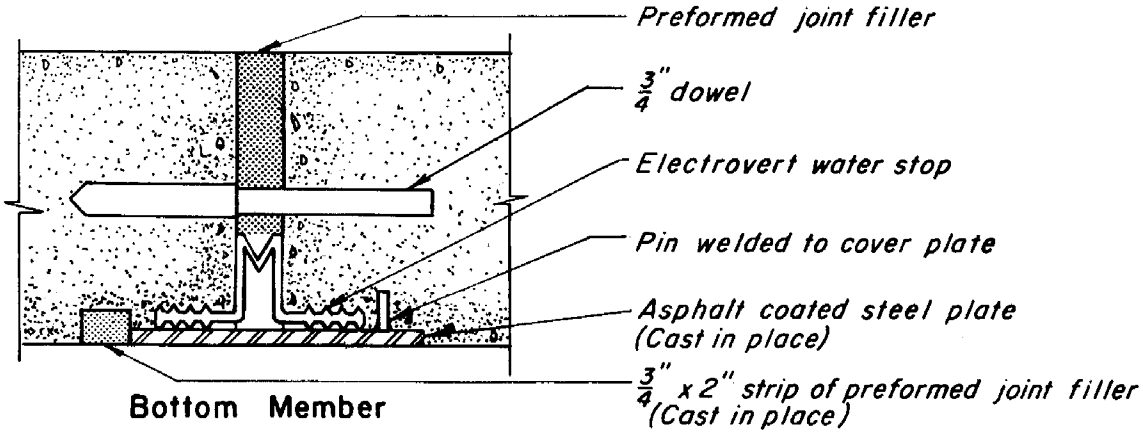
Use when construction drawings are to be reduced one half size

STEEL SCHEDULE									
Location	Mark	Size	Quan.	Length	Type	A	B	C	Total Length
CONDUIT ENCASEMENT									
	C 01				SPC				
	C 02				T2				
	C 03				Str				

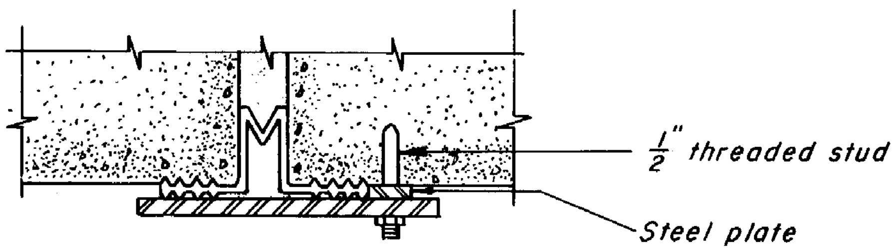
Use when construction drawings are to be reproduced full size

FIGURE E-4
R/C MONOLITHIC CONDUIT DETAIL
EWP Unit Portland, Oregon

Alternate 1

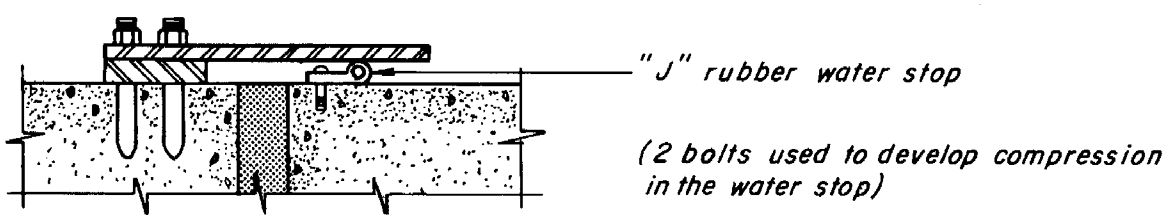


Bottom Member



Side and Top Member

Alternate 2



Alternate 3

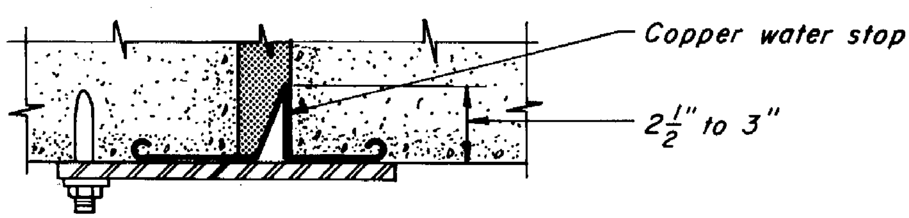
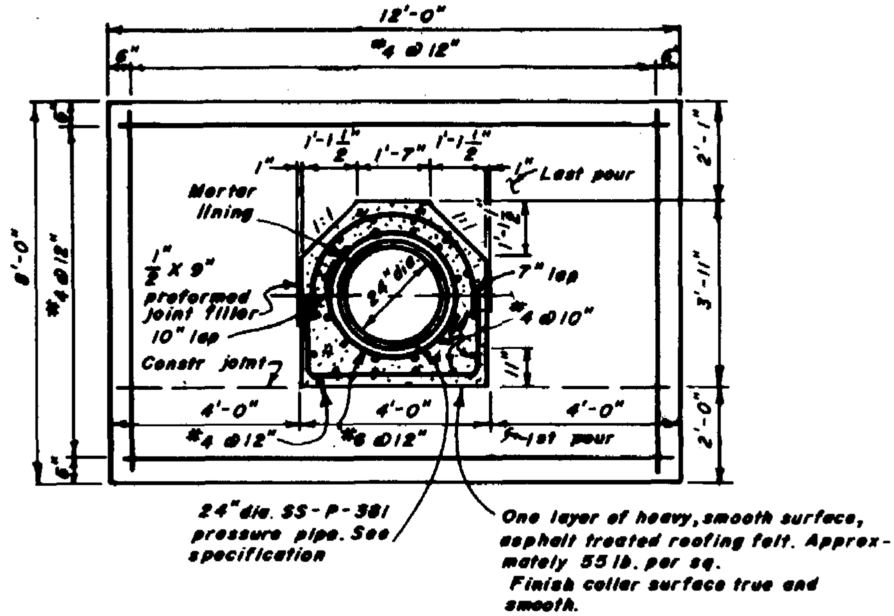


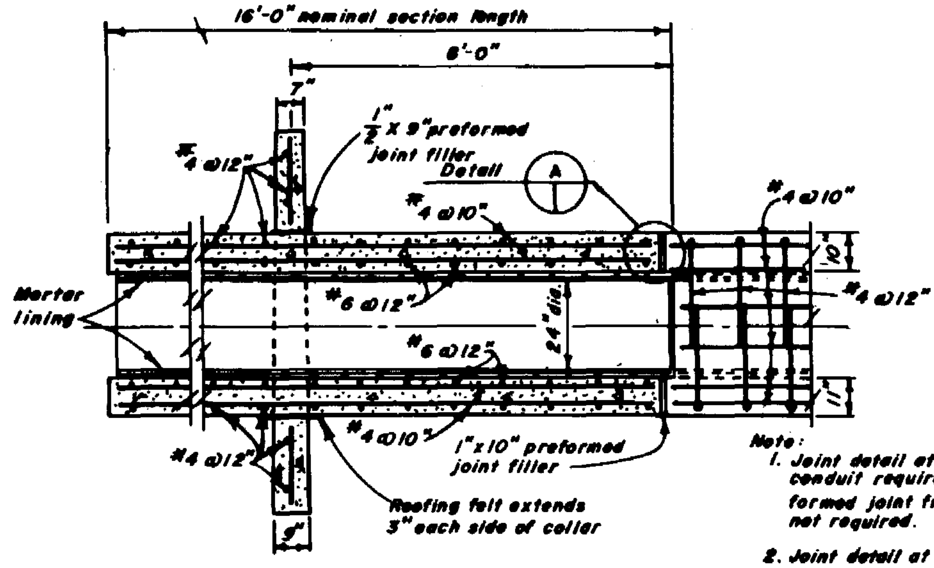
FIGURE E-5

MONOLITHIC OUTLET CONDUIT JOINT DETAILS

EWP Unit Portland, Oregon



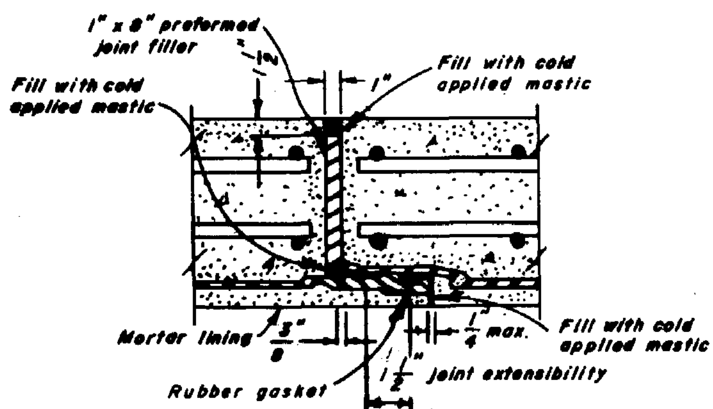
FRONT ELEVATION



Note:

1. Joint detail at bottom of conduit requires 1" x 10" preformed joint filler, 1 1/2" mastic not required.
2. Joint detail at sides of conduit requires 1" x 8" preformed joint filler with 1 1/2" mastic as shown in Detail A

SECTIONAL ELEVATION



DETAIL A

NOT TO SCALE

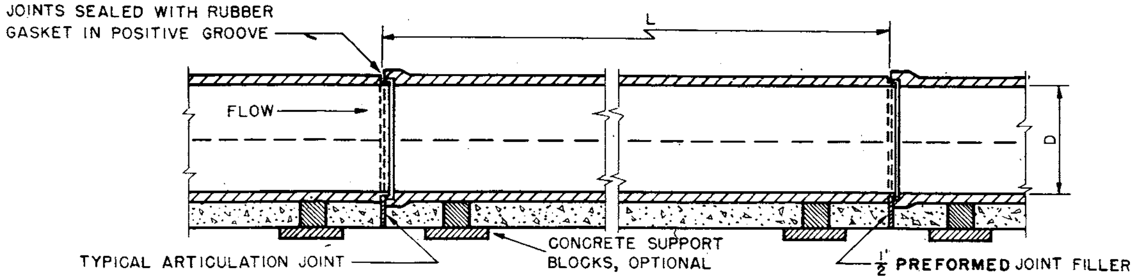
OUTLET CONDUIT AND ANTI-SEEP COLLAR

1 0 8
SCALE IN FEET

FIGURE E-6

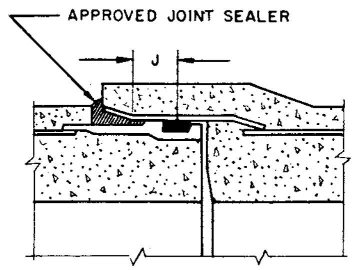
OUTLET CONDUIT COMPOSITE CONSTRUCTION

EWP Unit Portland, Oregon

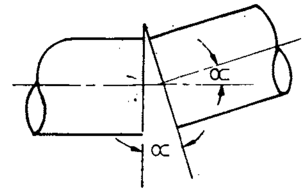


DETAIL OF PIPE CONDUIT
SECTION ON ℄–A2 CRADLE SHOWN

WHEN A1 CRADLE USED:
CUT LONGITUDINAL BARS AT 3" FROM EACH SIDE OF ARTICULATION JOINT. USE NO DOWELS.



JOINT EXTENSIBILITY



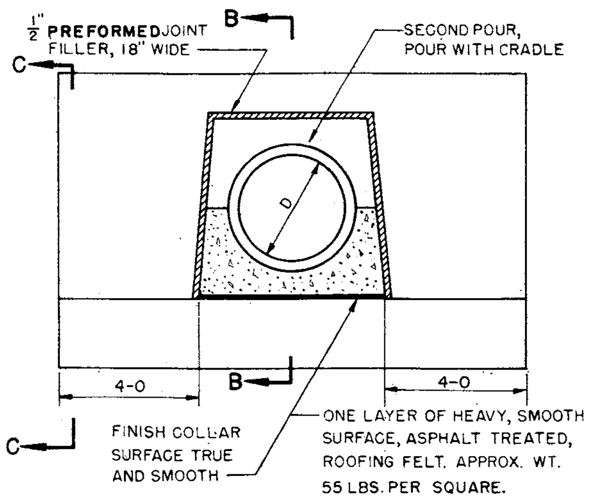
JOINT ROTATION CAPACITY

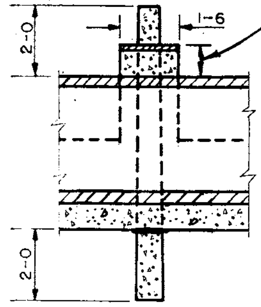
PIPE JOINT
DISPLACEMENT CHARACTERISTICS

L	J	∝
LENGTH OF PIPE SECTION	REQ'D JOINT EXTENSIBILITY	REQ'D JOINT ROTATION CAPACITY
FEET	INCHES	RADIANS

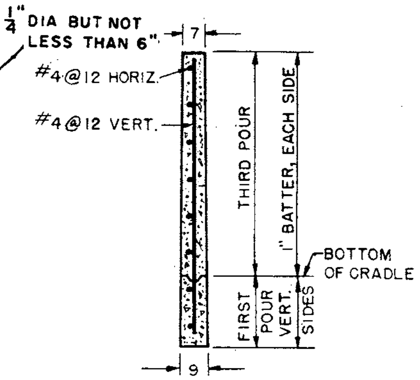
PRIOR APPROVAL OF PIPE AND PIPE JOINT DETAIL PROPOSED FOR USE, TO BE REQUIRED BY THE SPECIFICATIONS.

CLASS (a) DAMS MORE THAN 50 FT. HIGH, AND ALL CLASS (b) AND CLASS (c) DAMS





SECTION B-B

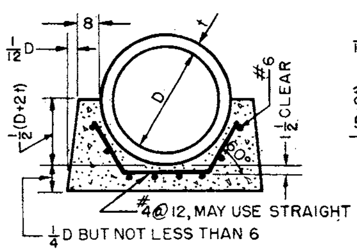


SECTION C-C
(SHOWING STEEL)

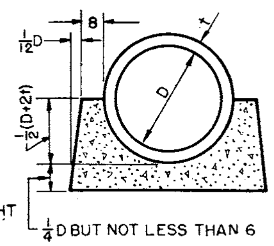
DETAIL SHOWN FOR EARTH FOUNDATION. FOR ROCK FOUNDATION, FOUND BOTTOM OF CRADLE ON ROCK LINE AND KEY COLLAR 6" INTO ROCK.

SIDES OF ANTI-SEEP COLLARS TO BE FORMED ABOVE BOTTOM OF CRADLE. MAX. SPACING OF COLLARS=25'.

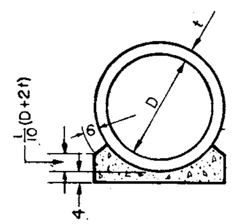
DETAIL OF ANTI-SEEP COLLAR



A1 CRADLE

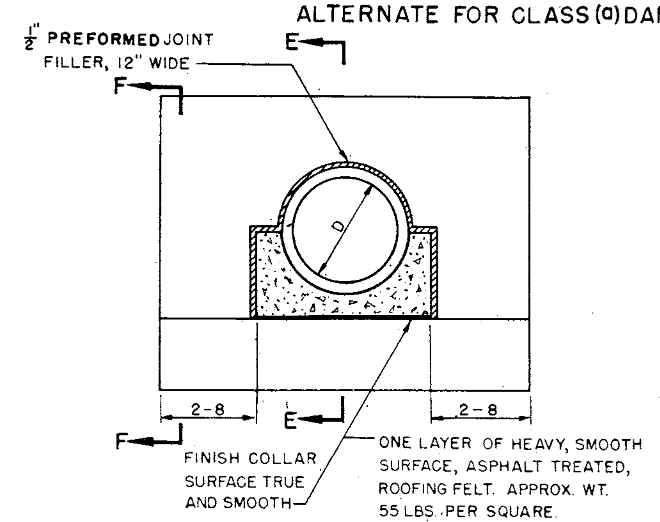


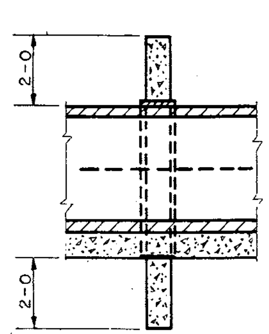
A2 CRADLE



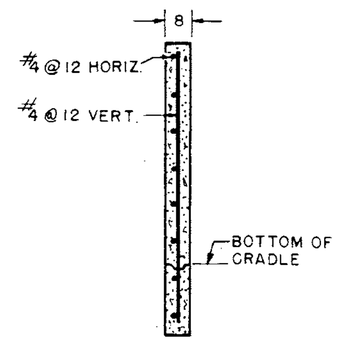
B1 BEDDING

ALTERNATE FOR CLASS (a) DAMS LESS THAN 50 FT. HIGH





SECTION E-E

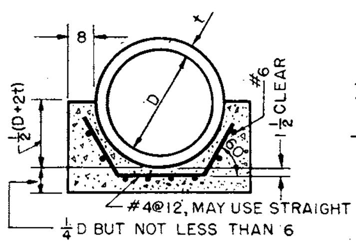


SECTION F-F
(SHOWING STEEL)

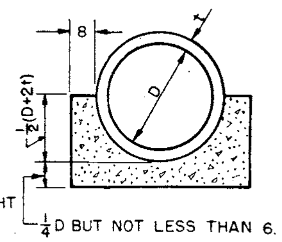
DETAIL SHOWN FOR EARTH FOUNDATION. FOR ROCK FOUNDATION, FOUND BOTTOM OF CRADLE ON ROCK LINE AND KEY COLLAR 6" INTO ROCK.

MAX. SPACING OF COLLARS=25'.

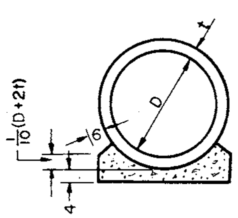
DETAIL OF ANTI-SEEP COLLAR



A1 CRADLE



A2 CRADLE



B1 BEDDING

PIPE AND CRADLE OR BEDDING ALTERNATES
MINIMUM THREE EDGE BEARING TEST STRENGTH LOAD IN POUNDS PER LINEAL FOOT OF PIPE FOR CORRESPONDING PIPE AND CRADLE OR BEDDING

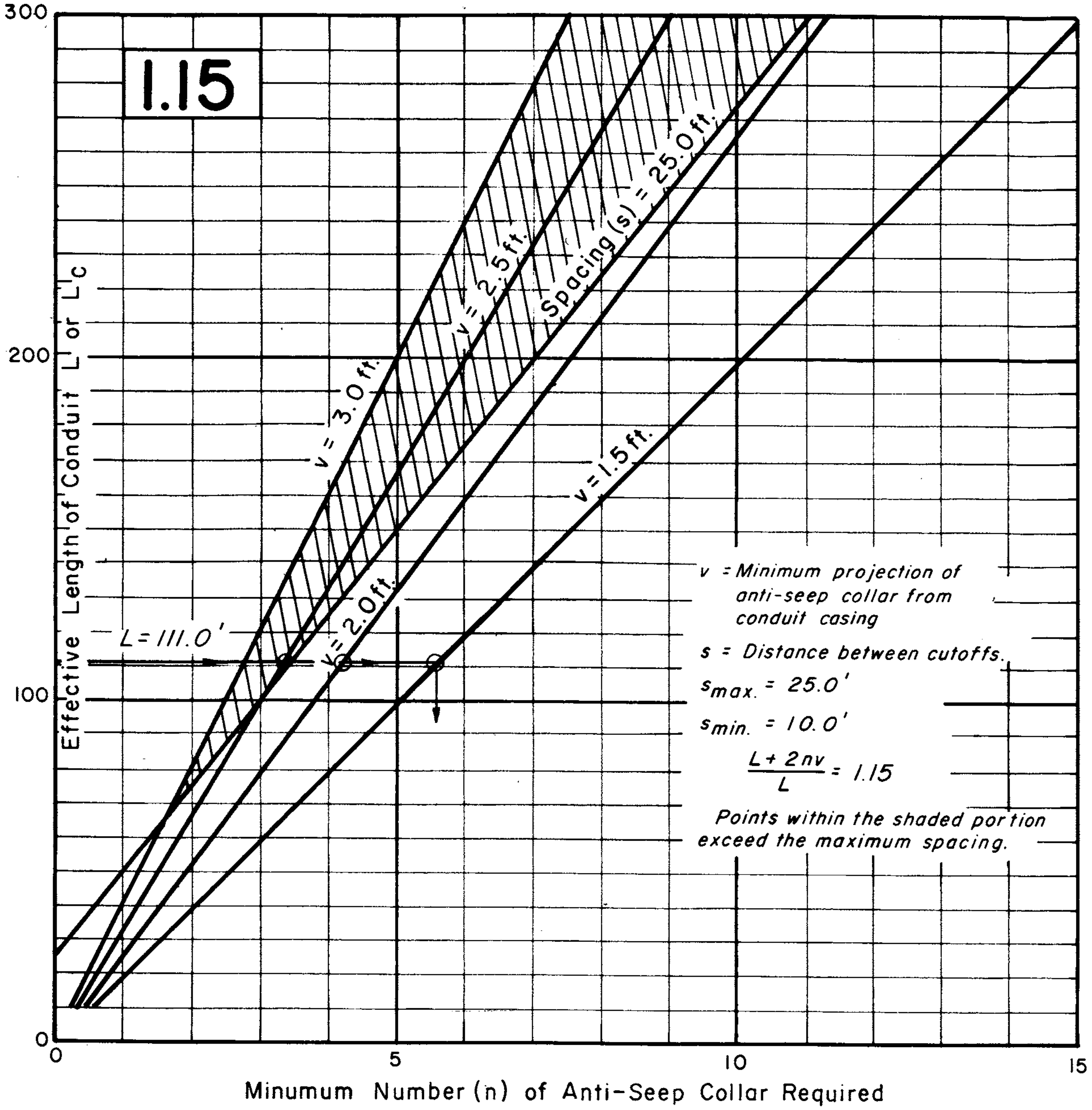
CRADLE OR BEDDING	PIPE SPECIFICATION		LOAD TO PRODUCE NOT MORE THAN 0.01 INCH CRACK	LOAD TO PRODUCE NOT MORE THAN 0.001 INCH CRACK
A1	AWWA	C-300		
		C-301		
		C-302		
	ASTM	C 361		
A2	AWWA	C-300		
		C-301		
		C-302		
	ASTM	C 361		
B1	AWWA	C-300		
		C-301		
		C-302		
	ASTM	C-361		

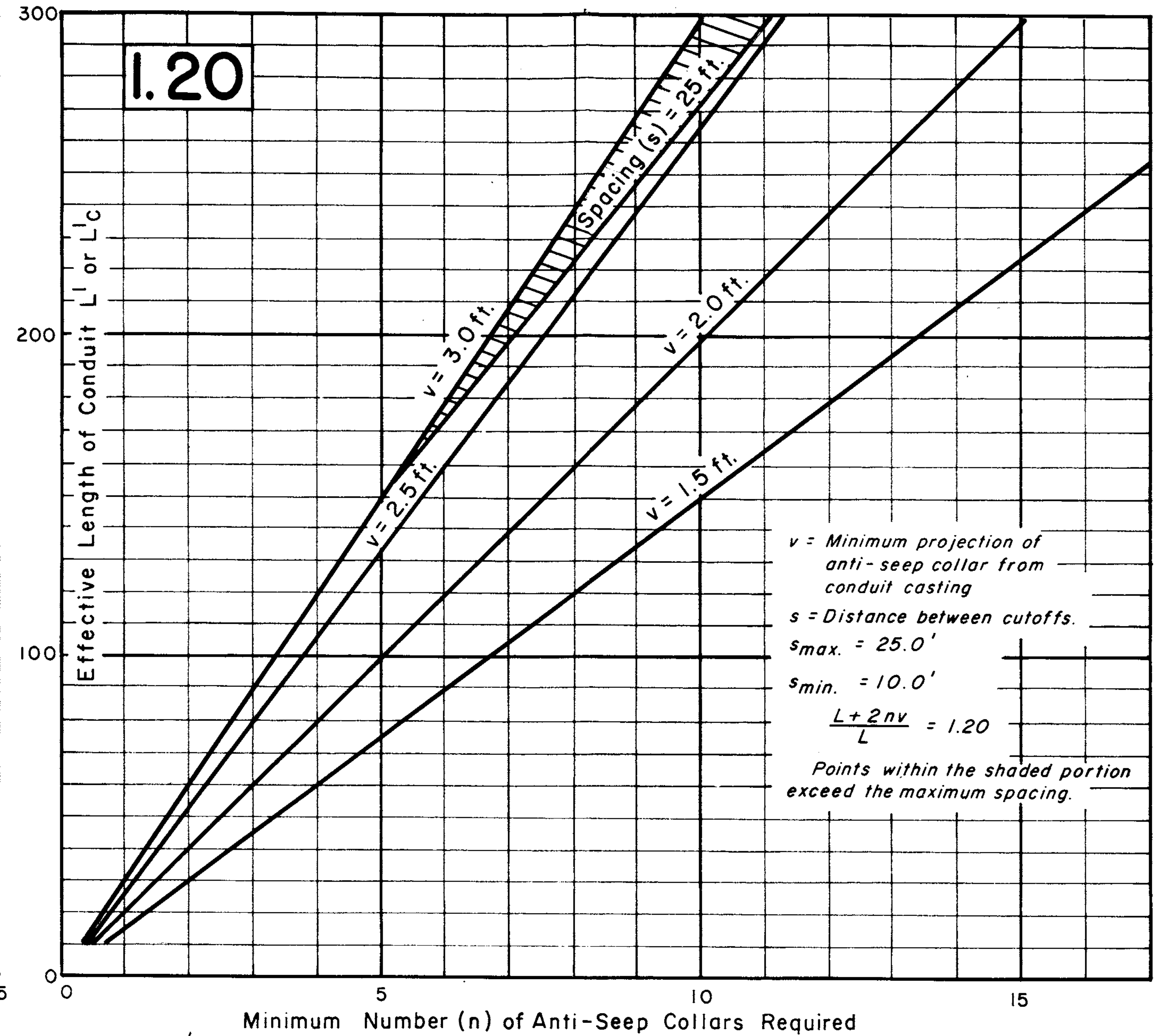
SCOPE:
1. Pipe Diameters:
D=24", 30, 36, 42, and 48

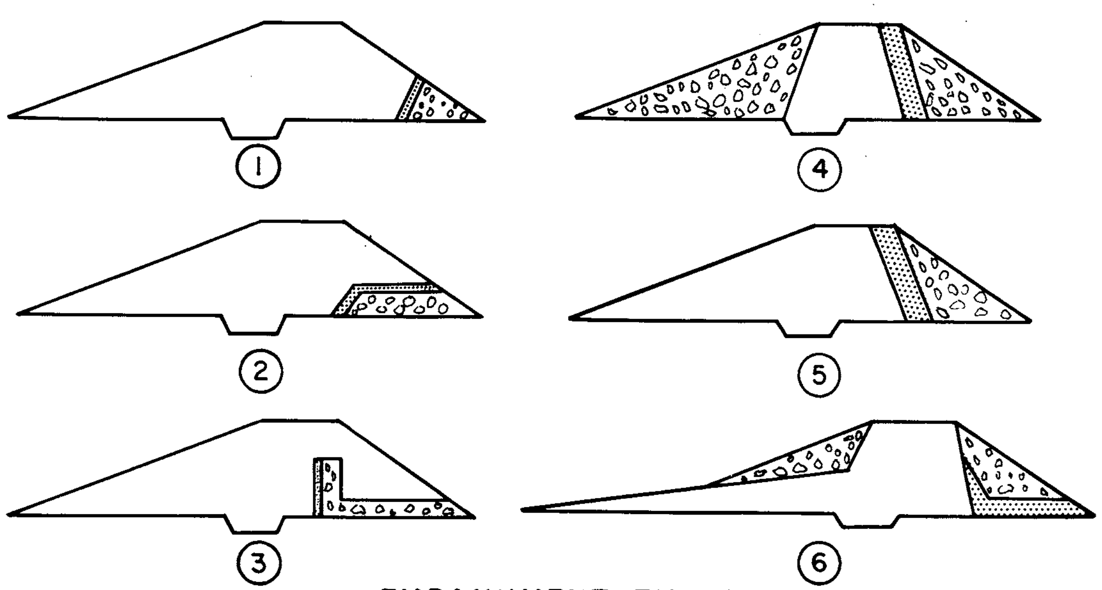
CRITERIA:
1. Materials (except pipe):
Concrete: Class B, f'c=4000 psi, fc=1600 psi
Reinforcing Steel: Intermediate grade
2. Applicable Criteria:
Engineering Memorandum SCS-27
Engineering Memorandum SCS-42 (rev. 2)
Technical Release No. 5
Technical Release No. 18

REFERENCE:
ES 154

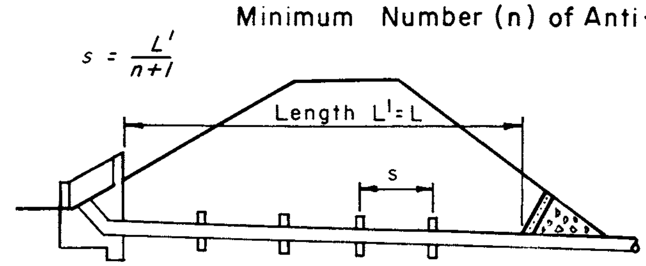
FIGURE E-7
OUTLET CONDUIT DETAILS
EWP Unit Portland, Oregon



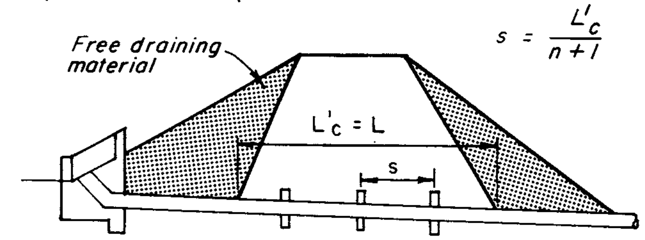




EMBANKMENT TYPES



HOMOGENEOUS EMBANKMENT



ZONED EMBANKMENT

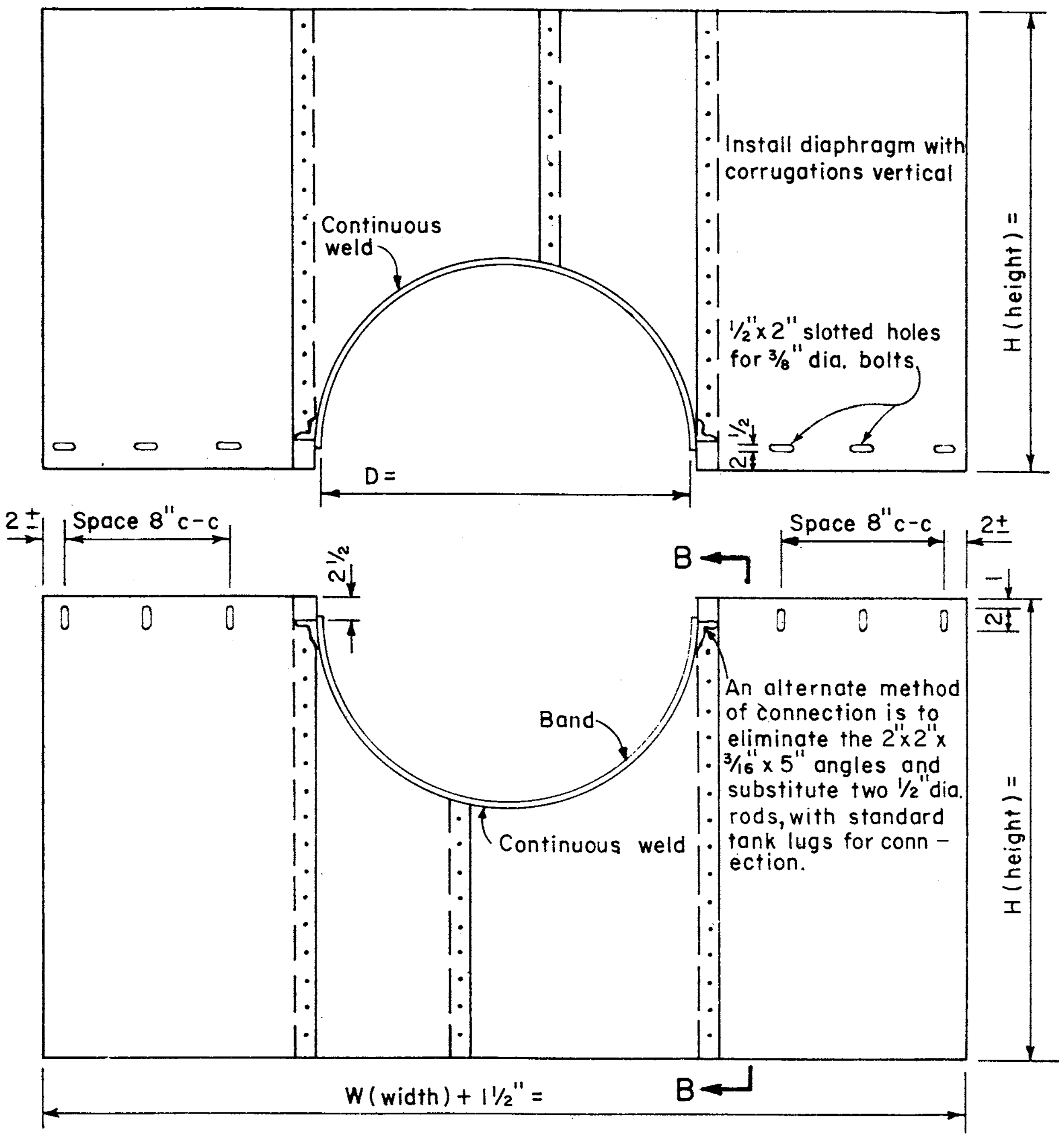
Core material in zoned embankment

SOIL CLASSIFIATION	EMBANKMENT TYPE	USE CHART
CL	1, 2, 3, 5	1.15
CH	4, 6	1.15
MH	1, 2	1.15
CL	4, 6	1.20
MH	3, 4, 5, 6	1.20
ML, SM	1, 2, 3, 4, 5	1.20

FIGURE E-8
CONDUIT ANTI-SEEP COLLAR SELECTION CHART
EWP Unit Portland, Oregon

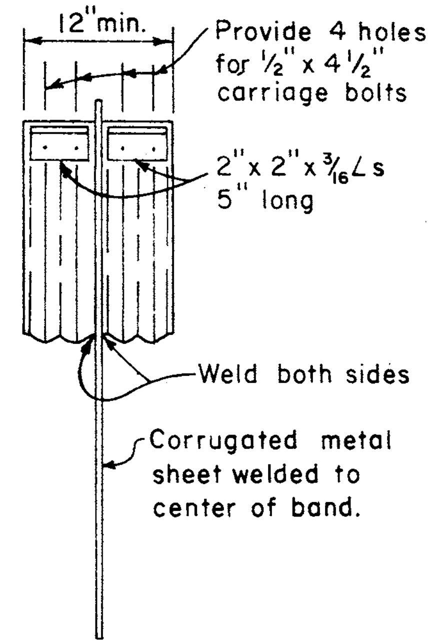
Notes:

1. All materials to be in accordance with applicable S. C. S. construction material specifications.
2. Unassembled diaphragms shall be marked by painting or tagging to identify matching pairs.
3. The lap between the two half sections and between the pipe and connecting band shall be caulked with asphalt mastic at time of installation.
4. Welding may be substituted for rivets in fastening 2" x 2" x 3/16" ∠s to pipe. Welds must be on each side of angles and on each corrugation ridge in contact with angle.
5. D = outside diameter of W.S. Pipe or nominal diameter of C.M. Pipe.
6. All corrugated metal pipe diaphragms shall be asphalt coated after shop fabrication has been performed.



ELEVATION OF UNASSEMBLED DIAPHRAGM

(No scale)



SECTION B - B

FABRICATION TABLE FOR C. M. DIAPHRAGM

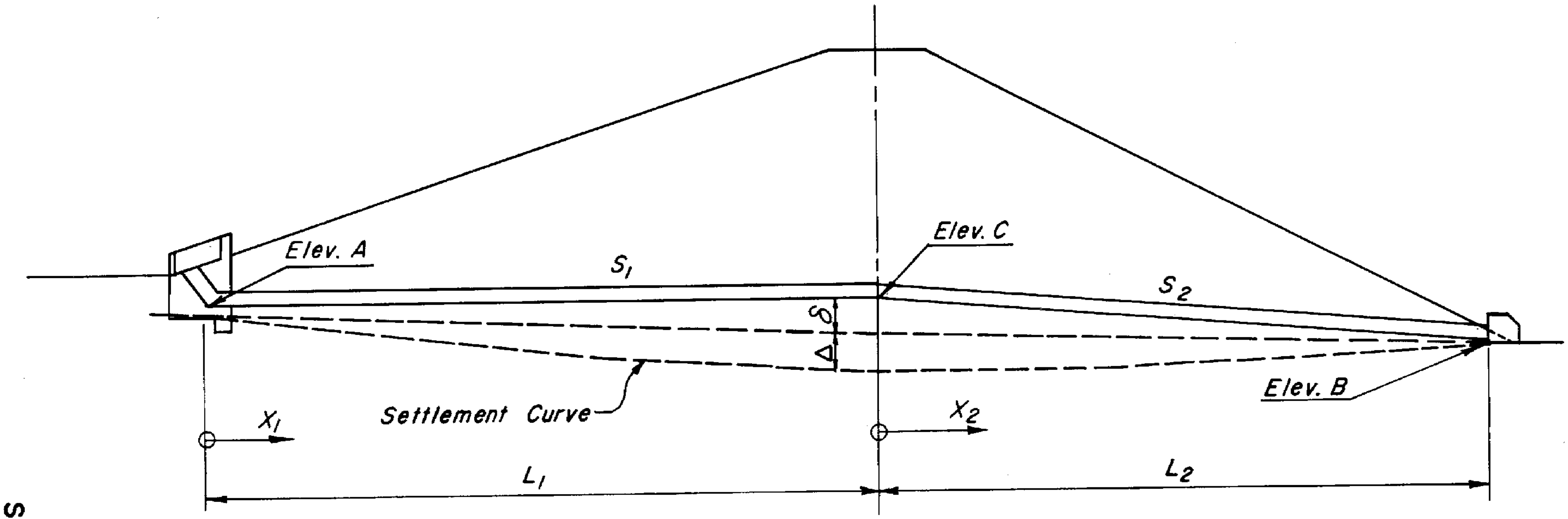
PIPE DIA.	GAGE *	GAGE **	NOMINAL DIAPHRAM SIZE	FABRICATION DIMENSIONS	
				W(WIDTH)	H(HEIGHT)
8	16	—	58 x 58	58 1/2	30 1/2
10	16	—	58 x 58	58 1/2	30 1/2
12	16	14	60 x 60	64	32 1/2
15	16	14	63 x 63	68	34
18	16	14	66 x 66	69 1/2	35 1/2
21	16	14	69 x 69	72	37
24	14	14	72 x 72	72	38 1/2
30	14	14	78 x 78	82 1/2	41 1/2
36	—	14	84 x 84	88	44 1/2
42	—	14	90 x 90	93	47 1/2
48	—	14	96 x 96	96	50 1/2
54	—	14	102 x 102	101 1/4	53 1/2

* Minimum gage for "Livestock Water Tanks and other dams not over 10 feet high.

** Minimum gage for all other dams - 12" dia. smallest size allowed.

FIGURE E-9

CORRUGATED METAL DIAPHRAGM ANTI-SEEP COLLAR

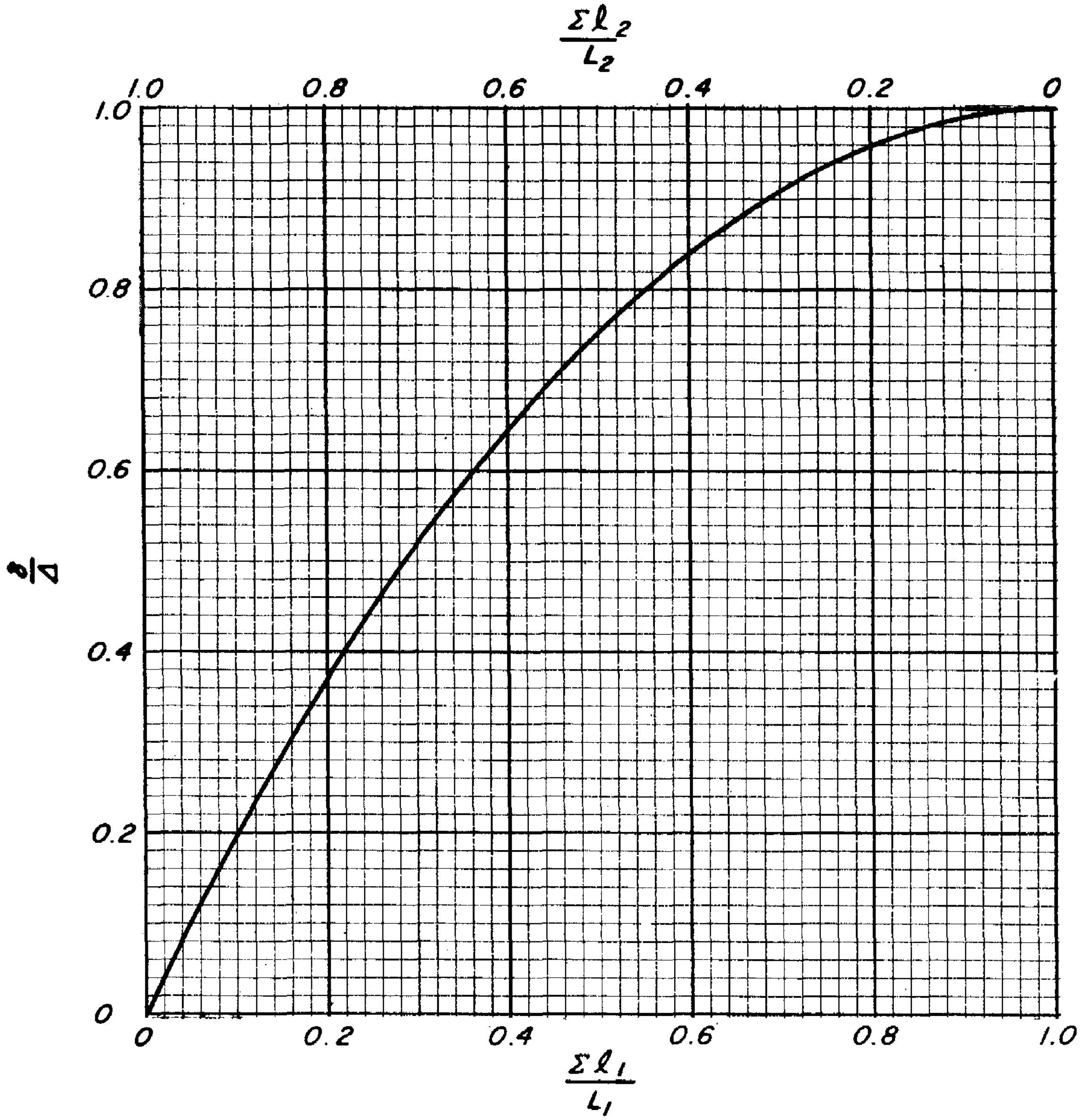


$$\Delta = \text{Max. settlement} = \delta_{max}$$

$$S_1 = \frac{\text{Elev. A} - \text{Elev. C}}{L_1}$$

$$S_2 = \frac{\text{Elev. C} - \text{Elev. B}}{L_2}$$

FIGURE E-10
SETTLEMENT CURVE AND SIMPLE CAMBER
EWP Unit Portland, Oregon



$$\delta = \frac{\Delta}{L_1^2} x_1^2$$

$$\delta = \Delta - \frac{\Delta}{L_2^2} x_2^2$$

FIGURE E-11

CONDUIT CAMBER ON PARABOLIC CURVE

EWP Unit Portland, Oregon

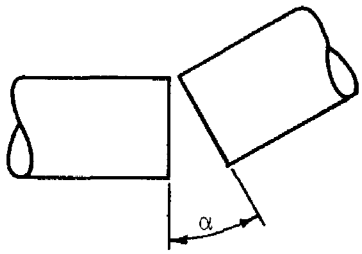
TABLE E-1

WALL THICKNESS
STANDARD R/C AND CYLINDER PIPE

Conduit	AWWA					ASTM	
Type / Inside Diameter	C-300	C-301 Lined Cylinder	C-301 Embedded Cylinder	C-302 $f'_c = 6000$ psi	C-302 $f'_c = 4500$ psi	C-361	C-76
inches	Wall Thickness t inches (minimum)						
12	-	-	-	2	-	2	1-3/4
15	-	-	-	2	-	2	1-7/8
16	-	-	1	-	2-1/8	-	-
18	-	1-1/8	-	2-1/4	-	2-1/4	2
20	3-1/4	1-1/4	-	2-3/8	-	-	-
21	-	-	-	2-3/8	-	2-3/8	2-1/4
24	3-1/2	1-1/2	2-1/4	2-1/2	3	2-1/2	2-1/2
27	-	-	-	2-5/8	3-1/4	2-5/8	2-5/8
30	3-1/2	1-7/8	2-1/4	2-3/4	3-1/2	2-3/4	2-3/4
33	-	-	-	2-7/8	3-3/4	2-7/8	2-7/8
36	4	2-1/4	2-1/4	3	4	3-1/8	3
42	4-1/2	2-5/8	2-5/8	3-1/2	4-1/2	3-3/4	3-1/2
48	5	3	3	4	5	4-1/8	4
54	5-1/2	-	4	4-1/2	5-1/2	4-1/2	4-1/2
60	6	-	4-1/2	5	6	5	5

TABLE E-2

CAMBER DATA



I. D. - In.	Approx. deflection per joint (α)	Sin α	Minimum radius of curve - 32 ft. lengths	Remarks
12	3° 05'	.0541	594'	
18	2° 07'	.0366	867'	
21	1° 50'	.0315	995'	
24	2° 10'	.0384	841'	Maximum joint gap = O.D. x sin α
27	1° 57'	.0345	938'	
30	1° 46'	.0312	1037'	
36	1° 29'	.0262	1230'	
42	1° 17'	.0227	1422'	

TABLE E-3

RECOMMENDED CORRUGATED STEEL PIPE GAGES

Conduit Diameter inches	Fill Height - feet			
	1 - 10	10 - 15	15 - 20	20 - 25
12 - 21	16	16	16	16
24	16	16	16	16
30	16	16	16	16
36	16	16	16	16
42	14	14	14	12

TABLE E-4

RECOMMENDED CORRUGATED OR SPIRAL ALUMINUM PIPE GAGES

Conduit Diameter inches	Fill Height - feet			
	1 - 10	10 - 15	15 - 20	20 - 25
12	16	16	16	16
18	16	16	16	14
21	16	16	16	14
24	16	14	14	12
30	14	14	14	12
36	14	12	12	10